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Research paper

Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences?

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HIGHLIGHTS

- Novel socio-cultural valuation framework for green infrastructure and climate impacts.
- People are more aware of present-day heat waves but more alarmed by future flooding.
- People tend to prefer diverse, familiar and visually attractive adaptation measures.
- Environmental education can increase support for effective adaptation measures.
- Results help planners prioritize effective and desired green infrastructure designs.

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ABSTRACT

Cities are particularly prone to the effects of climate change. One way for cities to adapt is by enhancing their green infrastructure (GI) to mitigate the impacts of heat waves and flooding. While alternative GI design options exist, there are many unknowns regarding public support for the various options. This study aims to fill this gap by performing a socio-cultural valuation of urban GI for climate adaptation that encompasses multiple dimensions: people's notion of and concerns about climate impacts, the degree to which people acknowledge the benefits of GI to alleviate such impacts, and people's preferences for different GI measures, including their willingness to pay (WTP). Data were collected through photo-assisted face-to-face surveys (n = 200) with residents in Rotterdam, the Netherlands, and linked to GI GIS data. Respondents had a notion of and concerns about climate impacts, but did not necessarily acknowledge that GI may help tackle these issues. Yet, when residents were informed about the adaptation capacity of different GI measures, their preferences shifted towards the most effective options. There was no information effect, however, on people's WTP for GI, which was mostly related to income and ethnicity. Our study shows that economic valuation alone would miss nuances that socio-cultural valuation as applied in this paper can reveal. The method revealed preferences for particular adaptation designs, and assists in detecting why policy for climate adaptation may be hampered. Understanding people's views on climate impacts and adaptation options is crucial for prioritizing effective policy responses in the face of climate change.

1. Introduction

Climate change impacts in cities have received increasing attention (EEA, 2012; UN-Habitat, 2011). It is becoming increasingly apparent that the combination of large populations, densely built structures and sealed surfaces seen in cities do not represent ideal conditions for tackling a changing climate. A climate in which weather events become more extreme may lead to an increase in flooding, droughts and heat stress, causing not only financial damage but also threats to public health and safety (Gao et al., 2015; IPCC, 2014).

Because many cities are already facing climate-related challenges, city administrations are developing climate adaptation strategies – often ahead of national plans (Carter et al., 2015). Nature-based adaptation options such as vegetated drainage

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ditches and stormwater retention ponds (Church, 2015) are increasingly recognized as alternatives to technical solutions for flood protection. To reduce the urban heat island effect, city governments have started embedding green space within streetscape design to create more comfortable urban environments (Norton et al., 2015). Green infrastructure (hereafter referred to as GI) is the "infrastructure of green spaces, water and built systems, e.g. forests, wetlands, parks, green roofs and walls that together can contribute to ecosystem resilience and human benefits through ecosystem services" (adapted from Demuzere et al., 2014). It is increasingly recognized that careful design and implementation of GI can contribute to climate adaptation (Matthews, Lo, & Byrne, 2015).

GI studies with a climate adaptation perspective typically focus on the two most challenging issues that cities encounter in the face of more frequent weather extremes: heat and flooding. The impacts of heatwaves and heavy rainfall events are magnified in urban areas because of the clustering of people and socioeconomic activity (EEA, 2012). GI can reduce urban heat and flooding by its shading, evaporative, interception and infiltration capacities (Demuzere et al., 2014; Derkzen, van Teeffelen, & Verburg, 2015). GI is also valuable for climate mitigation through its carbon storage function, for example in lawn-dotted (sub)urban USA (Visscher, Nassauer, Brown, Currie, & Parker, 2014). In the context of compact and low-lying Dutch cities, however, its main functionality lies in climate adaptation.

Beyond its role in climate adaptation and mitigation GI provides a range of other ecosystem services (TEEB, 2011). The ecosystem services framework is continuously developing and, although it has evoked a fair bit of criticism in the past decade (e.g. Silvertown, 2015), a majority of publications stresses the diversity of benefits provided by GI (Andersson et al., 2014; Hansen & Pauleit, 2014). Shortcomings of multiple benefit approaches are that such approaches do not always consider synergies and trade-offs among GI benefits or fail to assess GI values for different urban contexts (Sussams, Sheate, & Eales, 2015). As a result, prioritization of GI designs and their respective benefits becomes complicated, but is urgent given climate change impacts. At least two efforts can help GI prioritization: (i) empirical studies on GI synergies and trade-offs that transcend different scale levels and can be repeated in other localities (Demuzere et al., 2014); and (ii) studies that address people's needs and beliefs regarding GI benefits (Madureira, Nunes, Oliveira, Cormier, & Madureira, 2015). The latter is especially important for a successful implementation of GI-based climate adaptation strategies that provide benefits to the entire city and its residents.

To be able to address people's needs and beliefs regarding GI benefits, it is important to understand how citizens think about climate-related problems and the implementation of new GI. With such knowledge and the engagement of citizens, feasible and legitimate adaptation strategies that fit the local context can be developed (Anguelovski, Chu, & Carmin, 2014; Broto, Boyd, & Ensor, 2015). Moreover, involving people in the planning process can increase people's understanding of climate impacts and the need for adaptation can increase public support and inspire behavioural change (Baptiste, Foley, & Smardon, 2015; Demuzere et al., 2014). The difficulty lies in the existence of many unknowns: regarding people's notion of and concerns about climate impacts (i.e. the need to adapt), regarding the degree to which people acknowledge the benefits of GI to alleviate such impacts, and regarding people's preferences for the different GI measures, including their willingness to pay (WTP) for such measures (Byrne, Lo, & Jianjun, 2015; Madureira et al., 2015) (Fig. 1). Successful design of adaptation measures requires an understanding of these different unknowns, and how they relate to one another.

Existing socio-cultural valuation studies address different dimensions of climate impacts and GI benefits. In this context, multiple terms are used somewhat interchangeably, like awareness, perception, understanding and perceived importance (e.g. Burger, 2014; Byrne et al., 2015; Klemm, Heusinkveld, Lenzholzer, Jacobs, & Van Hove, 2015; Shackleton, Chinyimba, Hebinck, Shackleton, & Kaoma, 2015). More importantly however, these and other studies generally address only one dimension of the socio-cultural value. For example, Klemm, Heusinkveld, Lenzholzer, Jacobs et al. (2015) assessed citizens' perceptions of GI for thermal comfort but did not relate this to people's notion of or concern about heat. Likewise, Shackleton et al. (2015) studied how residents value tree benefits but did not extend to preferences for GI. Some studies tackle multiple dimensions, e.g., assessing perceptions of GI benefits and awareness and concerns about climate change (Byrne et al., 2015), but still refrain from looking into GI design preferences – which are more regularly captured by WTP exercises (Ng, Chau, Powell, & Leung, 2014). For urban planning, there is a need to couple public values with climate change strategies (Ordóñez Barona, 2015).

This study aims to fill this gap by performing a socio-cultural valuation of urban GI for climate adaptation that combines insights from the various dimensions listed in Fig. 1. Specifically, we address the following research question: *How do residents' views on climate impacts and GI benefits shape preferences for GI adaptation measures?* For the city of Rotterdam, the Netherlands, we conducted a survey among residents to assess the five dimensions and their relations. We assess the generality of our findings by (i) assessing the dimensions at three spatial scales associated with different types of urban GI (home, neighbourhood, city), (ii) comparing two neighbourhoods with a different demographic and GI character, and (iii) assessing how the dimensions are related to the current presence of GI in the respondents' neighbourhood. As such, the proposed method can generate improved understanding of people's views on climate impacts and the use of GI for adaptation, and can help detect why policy support for adaptation strategies may be hampered.

2. Methods

We designed a method addressing the five dimensions of analysis stated in Fig. 1. Each dimension was explored through a survey undertaken with residents in two neighbourhoods in Rotterdam, the Netherlands. To understand variation in responses and choices we have not only related the responses to socioeconomic characteristics of respondents but also to the presence of GI in the neighbourhood. The following paragraphs describe the case study and the different elements of the method in more detail.

2.1. Study area

Rotterdam is a major port, international commercial hub and the second city of the Netherlands with a diverse population of 620,000 people. The city is densely built, surrounded by water and with 90% of its surface below sea level. Two neighbourhoods are used as case studies (Fig. 2).

Tarwewijk and *Kralingen-West* represent typical Rotterdam neighbourhoods: one south of the river Meuse and one north; one in the lower socioeconomic strata and one middle-class. The two neighbourhoods were selected because they feature similar housing types but different character in terms of GI. The GI differs in abundance and diversity (Table 1) and provides diverse ecosystem services bundles in each neighbourhood: *Tarwewijk's* GI provides, as compared to other neighbourhoods in the city, a very small bundle of services whereas *Kralingen-West* is in the middle band (see Derkzen et al., 2015). Together with information about neigh-

Fig. 1. Flow diagram of five dimensions of people's views on green infrastructure (GI) as adaptation measures. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

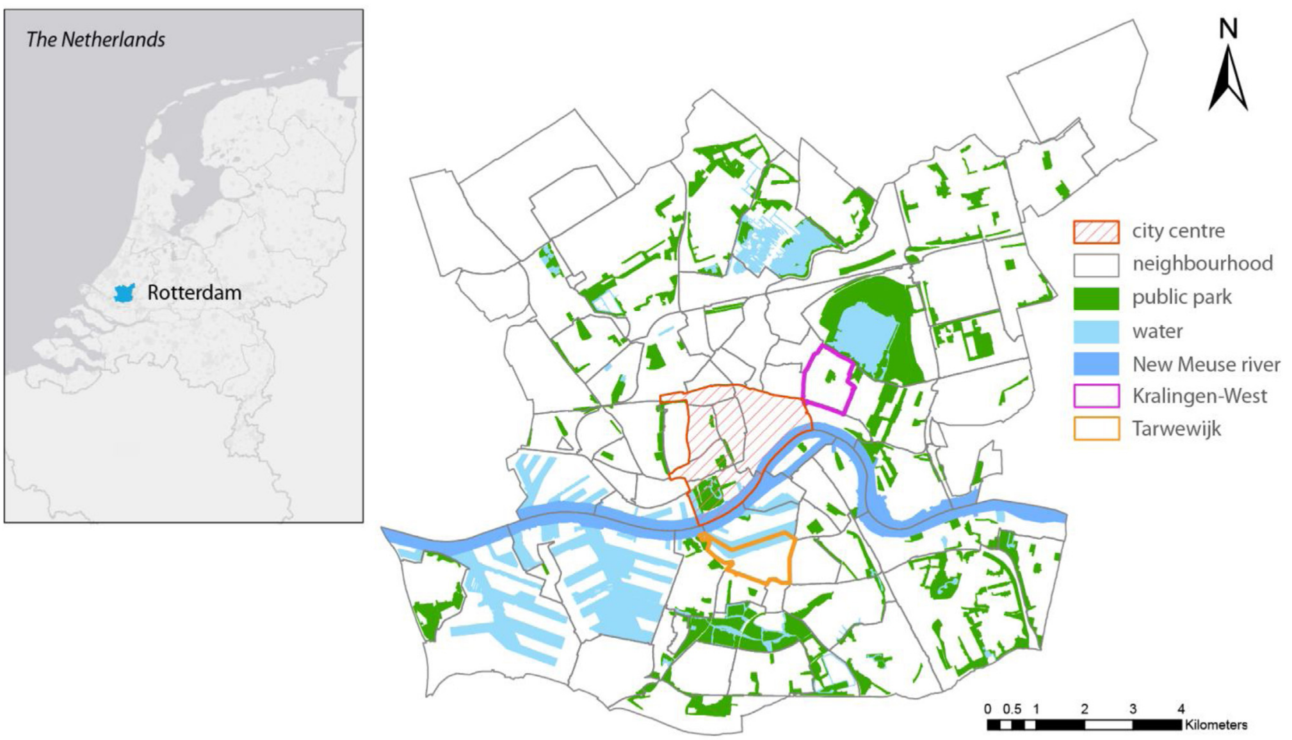

Fig. 2. Two case study neighbourhoods in Rotterdam, the Netherlands.

Table 1
The areal coverage (in percentages) by different green infrastructure (GI) types in Rotterdam and the neighbourhoods *Tarwewijk* and *Kralingen-West*, where surveys were conducted.

GI types	Rotterdam %	*Tarwewijk* %	*Kralingen-West* %
Woodland	2.7	0.0	0.0
Shrubs	2.0	0.7	2.1
Herbaceous vegetation	9.4	5.0	8.6
Garden	9.3	10.2	14.5
Street tree	6.6	6.1	10.4
Total excl. water	*35.0*	*29.5*	*35.7*
Water	14.8	25.8	0.5
Total incl. water	*44.6*	*47.7*	*36.1*

bourhood characteristics and liveability indicators obtained from municipal reports and websites and consultations with policymakers from different municipal departments, these neighbourhoods were selected as providing sufficient differentiation for this study.

Kralingen-West is a mixed neighbourhood with shops and restaurants and attracts more students and high-income residents than *Tarwewijk*. *Tarwewijk* was built in the same period, 1900–1930s, but features less diverse housing occupied by a young population with many immigrant families. There are numerous schools and playgrounds, whereas commercial services are clustered on the main roads encircling the neighbourhood. Several residents feel *Tarwewijk* is unattractive and unsafe and housing prices are generally lower than in *Kralingen-West*.

In terms of GI, *Kralingen-West* features more diverse and accessible GI than *Tarwewijk* where GI mainly consists of gardens and a few street trees. Both neighbourhoods include several pocket parks, although they tend to be stonier in *Tarwewijk*. *Tarwewijk* has a water front but a former industrial zone stands in between, making the former port area rather inaccessible. On the contrary, *Kralingen-West* boasts lots of accessible street greenery and attractive water sites. It also shares a border with Rotterdam's largest urban forest and lake (*Kralingse Bos*). Rotterdam's largest city park (*Zuiderpark*) is closer to *Tarwewijk*, yet still at 1 km distance.

2.2. Data

2.2.1. Survey

Data were collected through face-to-face surveys with 200 respondents (100 per neighbourhood) on mornings, afternoons and evenings during weekdays and weekends in August and September 2014. Because respondents needed to be residents (i.e. not visitors) interviewers went from door to door, using maps to ensure that interviews where held in different parts of each neighbour-

Fig. 3. Illustration of surveyed zip code areas (a) and the calculation of green infrastructure per zip code buffer (b) for *Tarwewijk* neighbourhood. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

hood (Fig. 3a). Each neighbourhood was entered from its northeast, southeast, southwest and northwest corner at least once and then surveyed street by street, including main roads, side streets, squares and courtyards. Interviewers rang every accessible doorbell and did not differentiate between housing types: we surveyed apartment buildings, elderly homes, row houses and detached houses. Only about one out of ten doors were opened; it was especially hard to gain access to apartment buildings. Among the people who opened the door, the response rate was about 25%.

The questionnaire was structured into five parts (following the dimensions in Fig. 1) with a total of 26 questions and two photo forms (Appendix A). Part one enquired about urban heat. Respondents were asked whether they noticed heat and, if yes, in which locations. They were also asked whether heat is a concern for them

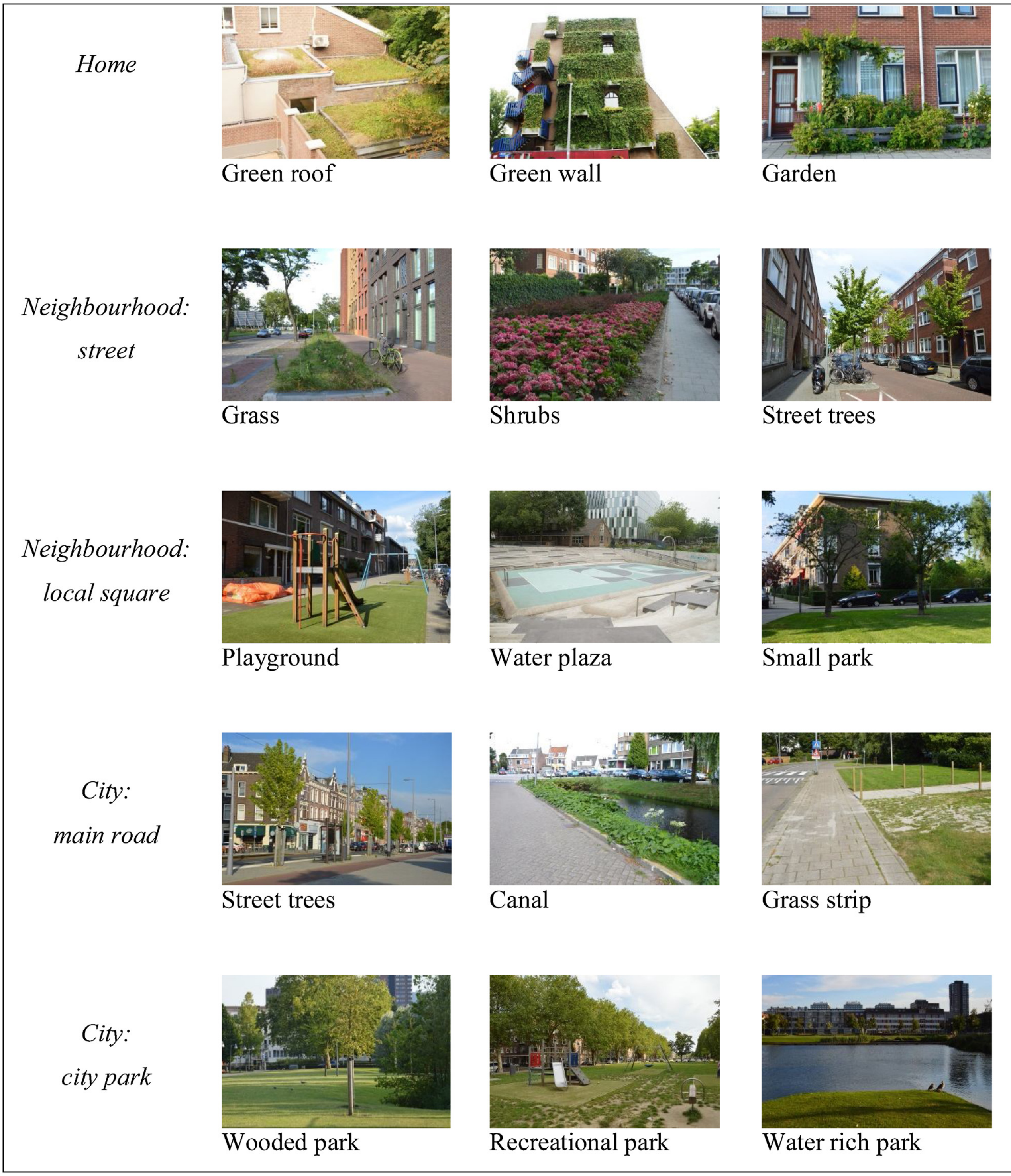

Fig. 4. Types of green infrastructure used in and photographed for the survey, organised across scales (home, neighbourhood, city). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

currently, and whether they have concerns about heat becoming a problem in the near future when the city is expected to face more extreme weather events. The same questions were asked about urban flooding in part two. Thirdly, respondents were asked to rate the two most and one least important ecosystem services provided by different GI types, using photos of typical urban GI setups (Fig. 4, and detailed descriptions in Appendix B). The question was: What benefits do you think that the photographed green and blue spaces provide? Photos were taken in July 2014 in areas nearby the case study neighbourhoods that resemble them in street layout, housing types and GI. An important consideration for taking photos was that the vegetation was young or recently planted as the photos meant to represent new measures. We avoided taking photos in *Tarwewijk* and *Kralingen-West* to minimise the possible bias of judged opinions in case respondents recognised the photographed places. Part four determined preferences for GI climate adaptation measures using photos of urban GI organized according to the scale of the infrastructure (Fig. 4). For each category, respondents could choose between three options. The typology covered the relevant types of GI in the study area, based on a quantitative assessment of GI in Rotterdam. The ES provided by GI differs per scale level, just as peoples' relation to GI does (Derkzen et al., 2015). This exercise included an informational intervention: half of the respondents (n = 100) received additional information about climate regulation benefits of the GI measures in Fig. 4 via symbols: water drops indicating flood protection capacity and thermometers indicating cooling capacity. Part five entailed an assessment of the WTP for establishing GI to mitigate climate impacts. WTP was presented as a tax per household per year and people had to indicate what level they were willing to pay for new GI measures, ranging from €0 to €40 per year. As part of the survey also some socioeconomic data were collected.

2.2.2. Sample demographics

The demographics of the study sample are comparable to census data of Rotterdam and the two neighbourhoods (Table 2). The sample showed a slight overrepresentation of women in both neighbourhoods, young residents and households without children in *Kralingen-West*, and middle aged residents and households with children in *Tarwewijk*. Dutch residents were found to be more willing to participate in the survey and are therefore overrepresented in our sample. This is partly a result of language issues but may also be because second generation residents categorise themselves as Dutch while they are immigrants according to official definitions.

2.2.3. Green infrastructure data

To relate survey responses to the spatial context of the respondent's residence we used spatial data of GI obtained from the Rotterdam municipality. These include detailed vector data ($<1\,m^2$) of woodland, street tree, tall shrub, short shrub, herbaceous vegetation, water and garden elements (see Derkzen et al., 2015). Zip codes from the questionnaires were used as a spatial reference. Because of the varying size of Rotterdam's zip code areas we used ArcGIS 10.2 to create 100 m buffers around zip code centroids as a proxy for the direct environment of the respondent. Next, these buffers were intersected with the GI layers so that a GI fraction could be calculated per zip code buffer (Fig. 3b).

2.3. Analysis

The analysis of the survey is conducted along three axes. First, the socio-cultural valuation of climate adaptation services is performed on three spatial scales: home, neighbourhood, and city. Although GI exists throughout these scales, each scale is managed by different entities and ruled by different values (Hunter & Brown, 2012). As to encompass the diversity among the scales but also enable prioritization for policy making (Demuzere et al., 2014), this study assesses the dimensions in Fig. 1 on all three scales but also includes an additional GI preference assessment that transcends the scales to support prioritization of either small- or large-scale GI. Second, we compare two neighbourhoods with their own demographic profiles and – more importantly – the one being 'greener' than the other. Third, the spatial analysis enables a comparison of people's views on climate impacts and GI measures with local data of currently available GI in the respondent's neighbourhood.

3. Results

3.1. Notion of and concerns about climate impacts

Fifty-nine to sixty-eight percent of the respondents expressed a notion of urban climate impacts (Table 3 *Notion*). There were no significant differences between the neighbourhoods. We found that the notion of temperature differences within the city was higher for women (75.9%) than for men (57.6%) ($\chi^2(1) = 7.598$, $p < 0.01$) while the notion of flooding was higher for people with higher education ($\chi^2(3) = 8.980$, $p < 0.05$). When asked where urban heat is noticed most, respondents indicated especially stony locations with little wind flow such as shopping streets, the city centre and residential homes. Roads, squares and parking areas were mentioned most frequently as areas considered prone to flooding. Flooding and heat were scarcely observed in parks, forests and areas along the river and canals (see Appendix C for all locations).

While there is a clear notion of climate impacts among respondents, not all consider heat and flooding to be personal problems (Table 3 *Concerns*). Currently, heat is more frequently a concern than flooding, with flooding being principally considered a future problem. Again, there were no significant differences among the two neighbourhoods. Multinomial logistic regressions show that both the notion of and concerns about heat and flooding were significantly lower for younger respondents, as well as for less educated respondents (Table 4).

Over a third of respondents personally experienced high temperatures as problematic. Most of them find the heat uncomfortable, suffocating or suffer from sweating or drowsiness (72%) while others have more serious health or sleep-related problems (28%). When respondents were asked whether they think that more extreme temperatures and heat waves, caused by climate change, will become problematic for the city in the future, more than half of respondents (56.5%, i.e. a strong increase as compared to the current situation) expressed this as being a concern.

Urban flooding is considered personally problematic for 25.5% of respondents. Most complaints were related to inconvenient puddles on streets, bike paths, sidewalks and parking lots (46%), followed by complaints about damage to houses and basements (35%), and problems of a more general nature: traffic jams, sewer problems or overall economic damage (19%). The numbers changed completely when people considered the near future: 76% (i.e. an increase of 196%) believed Rotterdam will increasingly have to deal with the consequences of more frequent and more extreme rainfall events, and will have trouble doing so.

Heat concerns were significantly more frequent amongst respondents who noticed temperature differences within the city ($\chi^2(1) = 4.052$, $p < 0.05$). The same holds for flooding ($\chi^2(1) = 26.008$, $p < 0.001$). Regarding heat, concerns about future problems were more common among people who experienced heat as problematic under current conditions ($\chi^2(1) = 6.112$, $p < 0.05$). Concerns about urban flooding were more common among respondents living in streets with little GI (Table 4).

3.2. Rating green infrastructure benefits

Respondents did not fully acknowledge the capacity of GI to mitigate local climate change effects. Ecosystem services with a more direct effect on people's health and wellbeing such as recreation and air purification were rated highest. Recreation or visual attractiveness was considered an important benefit of all types of GI except for green roofs (Fig. 5). Flood protection was rated as the second most important service in general and the foremost benefit of water rich parks, green roofs and grass strips. Third in line is air purification, which was rated the greatest benefit of wooded parks and after that, street trees. Cooling was less often mentioned as a benefit, although it rated second for green roofs and third for water rich parks. Carbon storage and especially traffic noise reduction were not rated very high. Traffic noise reduction was even considered the least important benefit for each GI type (Fig. 6).

Overall, respondents acknowledged GI's capacity to mitigate local flooding, whereas its function for temperature regulation is less acknowledged. To compare neighbourhood means we cre-

Table 2
Census and sample demographics of Rotterdam, *Tarwewijk*, and *Kralingen-West*.

Demographics	Rotterdam	*Tarwewijk*	*Kralingen-West*
Number of inhabitants[a]	618,355	12,065	15,115
Number of households[a]	311,190	6045	8585

	Census %	Sample %	Census %	Sample %	Census %
Gender[a]					
Female	51	54	48	54	51
Male	49	46	52	46	49
Age[a]					
16–25	15	15	21	33	22
26–45	37	37	45	31	40
46–65	30	40	26	26	25
>65	18	8	8	10	13
Household[a]					
Single	47	43	49	45	58
Without children	22	13	19	29	20
With children	29	44	33	26	22
Income[b]					
At or below modal[c]	53	79	68	58	58
1.5 to 2 times modal	34	19	27	31	31
More than 2 times modal	13	2	5	11	11
Ethnicity[a]					
Antillean/Aruban	4	9	9	0	2
Dutch	50	39	22	71	46
Moroccan	7	5	8	3	11
Surinamese	9	15	13	3	9
Turkish	8	14	13	2	7
Other non-Western	10	11	17	9	12
Other Western	12	7	18	12	13

[a] 2014 census data from the Dutch Central Bureau of Statistics, available via www.statline.cbs.nl.
[b] 2012 census data from the Dutch Central Bureau of Statistics, available via www.statline.cbs.nl.
[c] Census data distinguishes two categories only: low income and high income households, hence questionnaire categories have been merged to fit census categories.

Table 3
Notion of and concerns about climate impacts.

Climate impacts	Total (n = 200) %	*Tarwewijk* (n = 100) %	*Kralingen-West* (n = 100) %
Notion of heat and flooding			
Temperature difference between city and surroundings	59.0	53.0	65.0
Temperature difference within city	67.5	71.0	64.0
Flooding in city	60.0	63.0	57.0
Concerns about heat and flooding			
Heat personal problem	36.5	40.0	32.0
Heat problem for city (future)	56.5	57.0	56.0
Flooding personal problem	25.5	28.0	23.0
Flooding problem for city (future)	75.5	74.0	77.0

Table 4
Multinomial logistic regression results for the notion of and concerns about climate impacts and preferences for green infrastructure measures (only significant results included).

Multinomial logistic regression results	Odds ratio	Confidence interval		p- value
		Lower	Upper	
Notion of urban flooding				
Less noticed when aged 16–25	2.51	1.09	5.78	0.03
Less noticed when education is max high school	2.73	1.28	5.82	0.01
Concerns about heat as a personal problem				
Less when aged 26–45	2.32	1.07	5.00	0.03
Less when ethnicity is Dutch	2.04	1.04	4.00	0.04
Less when total GI fraction is smaller	0.03	0.00	0.71	0.03
Concerns about heat as a future city problem				
Less when aged 16–25	2.52	1.10	5.77	0.03
Less when aged 26–45	3.11	1.46	6.61	0.00
Less when education is max high school	2.73	1.28	5.81	0.01
Concerns about flooding as a future city problem				
Less when total GI fraction is larger	81.34	1.80	3682.43	0.02
Preferences for green infrastructure measures				
Street trees preferred over shrubs when GI fraction is smaller	0.01	0.00	0.33	0.01
Water rich park preferred over wooded park when GI fraction is larger	43186.26	2.98	6.25×10^8	0.03

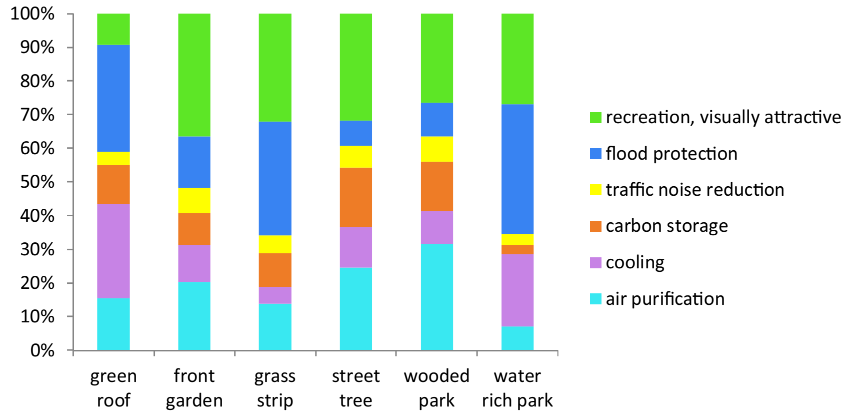

Fig. 5. Most important ecosystem services provided by green infrastructure types, as indicated by respondents. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

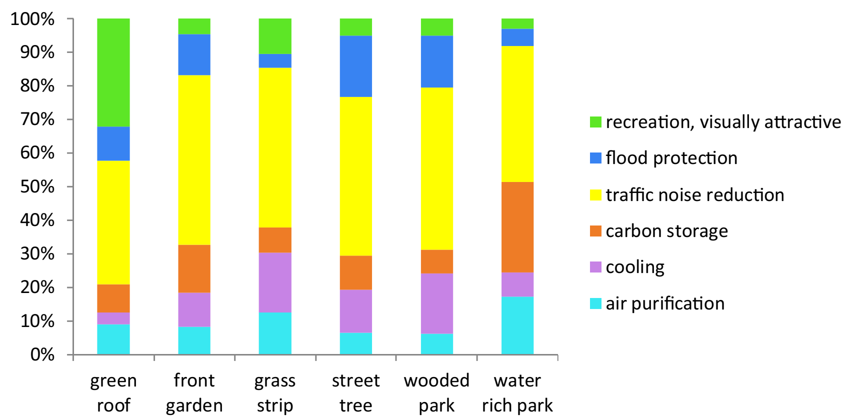

Fig. 6. Least important ecosystem services provided by green infrastructure types, as indicated by respondents. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

ated composite variables of the number of times that cooling and flood protection were rated as most important (ranging 0–9) and least important benefits (ranging 0–5). Respondents in *Tarwewijk* elicited significantly more climate benefits as most important (4.81 ± 1.91 times) than respondents in *Kralingen-West* (4.09 ± 1.83 times) ($t(198) = 2.724$, $p < 0.01$). Respondents were more likely to recognize flood protection benefits if they live in GI-rich areas ($r = 0.160$, $p < 0.05$), possibly because they notice that vegetated spaces do not flood as much as surrounding streets do. Recognition of cooling benefits did not increase with GI fraction, confirming the perceived lesser importance of temperature regulation. Also, respondents noticing and concerned about climate impacts were no more likely to recognize climate services than those not noticing and unconcerned.

To assess the importance of the six ecosystem services without linking them to specific GI types, we included an exercise in which respondents ranked the six services according to general importance for their livelihood (1 = high, 6 = low). Air purification was regarded the most important ecosystem service in urban environments (average rank of 2.02), followed at some distance by flood protection (3.51), carbon storage (3.53), recreation (3.64), cooling (3.88) and finally noise reduction (4.41). Recreation ranked low compared to the first exercise in which it was considered the most important benefit related to the six GI types. In turn, air purification and carbon storage climbed up in rank. This indicates that people find clean air very important in cities, and that they worry about wet feet and global warming. Interestingly, respondents who experienced heat as problematic ranked the cooling benefit higher than respondents who had no problems with heat ($\chi^2(5) = 11.475$, $p < 0.05$), while this relation did not appear from the photo exercise in which the benefits were assessed per GI type.

3.3. Preferences for green infrastructure measures

Respondents showed a preference for GI that is diverse, aesthetically attractive and familiar over GI that is rather simple or unfamiliar (Table 5). Gardens (48.0%) were the most preferred measure at home level, followed by green roofs (37.4%). The low score for green walls (14.6%) may be explained by the relative unfamiliarity and people's worries about their maintenance. Green walls and roofs were more popular among highly educated respondents ($\chi^2(6) = 15.907$, $p < 0.05$) whereas gardens were especially favoured by respondents with children ($\chi^2(2) = 7.592$, $p < 0.05$).

At the neighbourhood level most people preferred streets with shrubs (50.8%) or trees (39.2%) over grass strips (10.1%) – this may be because grass strips are easily littered and attract dogs. Grass was more frequently chosen by respondents with low education levels ($\chi^2(6) = 17.701$, $p < 0.01$) whereas trees were preferred over shrubs when respondents lived in GI-poorer streets (Table 4). Local squares were preferably transformed into small pocket parks with grass, shrubbery and some trees (55.3%). Less preferred options were a playground (26.1%) or water plaza (18.6%). Water plazas are not very common and look rather grey because of their concrete surface, which may explain their relative unpopularity. However, the water plaza was significantly more popular among people who noticed urban flooding ($\chi^2(2) = 6.395$, $p < 0.05$). Those noticing

Table 5
Preferences for green infrastructure measures.

Measures per scale level	Total (n = 200) %	Those who did not receive climate information (n = 100) %	Those who received climate information (n = 100) %	Sign.	*Tarwewijk* (n = 100) %	*Kralingen-West* (n = 100) %	Sign.
Home				*			**
Front garden	48.0	54.5	41.4		58.2	38.0	
Green roof	37.4	28.3	46.5		33.7	41.0	
Green wall	14.6	17.2	12.1		8.2	21.0	
Neighbourhood: street				*			***
Shrubs	50.8	61.0	40.4		61.0	40.4	
Trees	39.2	27.0	51.5		26.0	52.5	
Grass	10.1	12.0	8.1		13.0	7.1	
Neighbourhood: local square				***			**
Small park	55.3	49.5	61.0		44.0	66.7	
Playground	26.1	37.4	15.0		33.0	19.2	
Water plaza	18.6	13.1	24.0		23.0	14.1	
City: main road				**n.s.**			*
Canal	48.2	47.5	49.0		44.0	52.5	
Trees	36.7	36.4	37.0		34.0	39.4	
Grass	15.1	16.2	14.0		22.0	8.1	
City: city park				**			***
Wooded	46.0	36.0	56.0		34.0	58.0	
Recreation	34.5	44.0	25.0		46.0	23.0	
Water rich	19.5	20.0	19.0		20.0	19.0	

n.s. = not significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

flooding also tended to prefer small parks, whereas those not noticing flooding preferred the stonier playground – just like households with children ($\chi^2(2) = 20.752$, $p < 0.001$).

At the city level people chose canals (48.2%) and trees (36.7%) rather than grass strips (15.1%) as a measure along main roads, despite remarks made by several respondents about the risks of children falling in the water and cars hitting trees. Women were more likely to prefer grass whereas men preferred water canals ($\chi^2(2) = 6.486$, $p < 0.05$). Considering city parks, wooded parks were most popular (46.0%), followed by parks designed for recreation (34.5%) and those largely consisting of water (19.5%). A much heard argument in favour of the wooded park was its suitability for a combination of uses: sports, play, rest and enjoying nature. Especially respondents with high education levels chose the wooded park, whereas lower educated respondents were more inclined to prefer parks designed for recreation ($\chi^2(6) = 13.319$, $p < 0.05$). Spatial analysis revealed that respondents living in a neighbourhood with a larger GI cover more often preferred water rich parks over wooded parks (Table 4).

Preferences for GI adaptation measures were significantly different between the two neighbourhoods (Table 5). Green walls, roofs, street trees, small parks, water canals and wooded parks were popular in *Kralingen-West* whereas gardens, shrubs, playgrounds, water plazas, grass strips and recreational parks were fancied in *Tarwewijk*. This may indicate that *Tarwewijk* has a greater need for accessible GI that can be used for leisure, sports and play. The demand in *Kralingen-West* is oriented towards more natural GI. Indeed, *Kralingen-West* neighbours the city's largest urban forest and features more local parks than *Tarwewijk* which has less green areas and only a few public sport courts, while it is known as a neighbourhood where many children live.

The informational intervention resulted in a shift to more effective GI measures (Table 5). At home level, respondents who received climate adaptation information favoured the green roof option over a garden or green wall, and at street level the information led to more people choosing trees over shrubs or grass. For local squares, water plazas gained preference over playgrounds, and at city level the information reduced interest in recreational parks in favour of wooded parks. Although preferences were clearly influenced by the informational intervention, respondents were not conscious of this effect. When inquiring about people's main reason to choose a specific measure, 30% of respondents who did not receive any climate information indicated to choose a measure because of its contribution to climate adaptation against 25% of those who did receive the information. For both groups a majority indicated that measures are primarily chosen based on visual attractiveness and usefulness (50%), or because these GI types are currently lacking in the neighbourhood (22%). Socioeconomic factors do not explain the variation in reasons for preferences provided, nor does GI fraction or the notion of and concerns about climate impacts. The only significant relation exists for respondents who foresee future problems with urban heat: they were more eager to base their choice for a GI measure based on its expected adaptation effect ($\chi^2(2) = 8.288$, $p < 0.05$).

Apart from asking which GI type respondents prefer for each scale, the questionnaire also inquired about their two overall favourites out of the six GI types discussed in section 3.2. Results show a clear tendency of respondents to prefer large-scale GI over small elements: wooded (38%) and water rich parks (24%) were preferred most, followed by street trees (15%), front gardens (10%), and finally green roofs (7%) and grass strips (6%). Whereas green roofs grew in popularity for people living in GI-rich areas, this did not change public preferences for grass – even in areas with limited grass cover people rather had trees or green roofs. So on top of the established preferences per GI category, respondents indicated that the demand for large-scale GI has priority over that for small-scale GI.

3.3.1. *Willingness to pay for green infrastructure measures*

About two thirds of respondents were willing to pay for GI measures and most of them agreed that a tax of €15 per household per year would be acceptable (Table 6). Respondents who chose a WTP of €0 believed it is not worth their money (35%) or were unsatisfied with municipal policy and find current taxes already too high (28%).

Table 6
Willingness to pay (WTP) for green infrastructure measures.

WTP (tax per household per year)	Total (n = 200) %	Without climate info (n = 100) %	With climate info (n = 100) %	*Tarwewijk* (n = 100) %	*Kralingen-West* (n = 100) %
€0	34.5	37.0	32.0	39.0	30.0
€5	17.5	21.0	14.0	22.0	13.0
€15	34.0	29.0	39.0	28.0	40.0
€40	14.0	13.0	15.0	11.0	17.0
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

Others found it unimportant or believed it does not have priority for municipal expenses (16%). Additionally, there is a group of people who either did not have enough money because of unemployment, or preferred another way of contributing e.g. through community initiatives (21%).

Table 6 shows that respondents in *Kralingen-West* were willing to pay more than respondents in *Tarwewijk*. Differences are not significant for all monetary attributes ($\chi^2(3) = 6.892$, $p = 0.075$) but are significant for the lower and higher attributes (€0-5 and €15-40, $\chi^2(1) = 6.490$, $p = 0.011$). Respondents who received climate information showed a slightly higher WTP than respondents who did not receive this information (Table 6), but differences are not significant. WTP was also not related to GI fraction or higher for people for whom the climate adaptation effect was the main reason to choose GI measures. Differences in WTP are mainly explained by socioeconomic differences: households with a higher income ($\chi^2(4) = 21.252$, $p < 0.001$) and of Dutch ethnicity ($\chi^2(1) = 8.42$, $p < 0.01$) showed a greater WTP than households with a lower income or of non-Dutch ethnicity. The results indicate that WTP is independent of people's notion of and concerns about climate impacts, and their rating of GI in terms of climate adaptation benefits.

4. Discussion

We performed a socio-cultural valuation of urban GI for climate adaptation. Our analysis encompassed multiple dimensions that determine socio-cultural values and stated preferences for climate adaptation measures, and we studied their relation. Given the wide range of GI measures we analysed three spatial scales and related socio-cultural values to the current presence of GI in the city. The proposed multi-dimensional method, ranging from measuring problem notion to willingness to pay for adaptation, proved useful in clarifying some of the unknowns regarding residents' views on climate impacts and public support for the use of GI in climate adaptation strategies.

In relation to our main objective the results indicate that residents expressed a notion of urban heat and flooding and considered these serious future challenges, but did not always realize how GI may act as an adaptation measure. GI benefits with a more direct effect on people's health and wellbeing, such as recreation and air purification, were better understood than less direct benefits. However, we found that providing information about GI benefits, in this case climate adaptation capacity, can increase public support for adaptation measures. We also found that preferences for GI and concerns about climate change impacts were to a certain degree related to current GI availability.

This study is not the first to assess socio-cultural values for ecosystem services or climate related issues, but differentiates itself from other studies in four ways: by (i) presenting a multi-dimensional image of residents' views and preferences, (ii) revealing how economic valuation may miss certain nuances of socio-cultural values, (iii) offering insight into how policy intervention is possible and, (iv) relating survey responses to the spatial context of the respondent's residence. We next elaborate on these four features.

First, we presented a multi-dimensional image of residents' views and preferences. Studies in the same field often focus on a single dimension of our methodology, for example by measuring perceptions of a range of GI benefits (Madureira et al., 2015). Other studies consider two dimensions but still miss the dimension of problem awareness and are typically limited to a single GI type, e.g. perceptions of plant richness and preferences for plant management in an urban park (Muratet, Pellegrini, Dufour, Arrif, & Chiron, 2015). An inclusive approach, as exemplified here, allows for a more comprehensive understanding of people's views and preferences – in this case regarding urban heat, flooding, and the use of GI for climate adaptation.

The two neighbourhoods revealed different socio-cultural values for climate impacts and GI measures. Residents of GI-poor *Tarwewijk* more often acknowledged GI's climate benefits, encountered more heat and flood prone locations and experienced more personal problems with climate impacts. This may lead to the conclusion that *Tarwewijk* residents would easily accept the most effective adaptation measures. However, when we asked residents for their opinion they stated a need for functional GI that can be used for leisure, sports and play – much more than in *Kralingen-West* where more natural GI was preferred. This example shows how the multi-dimensional approach allowed us to explore nuances between the different dimensions that would not have appeared from assessing just one or two of the dimensions. Urban planners need such nuanced information to create GI measures that are effective for adaptation but also fit the local context. The need to tailor GI design to diverse local demands is a result of urban studies all over the world (e.g. Jim and Shan, 2013; Priego, Breuste, & Rojas, 2008).

Second, socio-cultural valuation as applied in this paper revealed more nuances than economic valuation alone would. When viewed in isolation, the WTP exercise in this study may lead to the conclusion that environmental education cannot increase public support for climate adaptation measures, as providing information on GI's adaptation capacity did not change people's WTP. This may indicate that urban GI is seen as a public good for which the government is responsible. However, the information did affect people's preferences for GI designs. While the monetary valuation was strongly determined by socioeconomic characteristics of the respondents, preferences were affected by the information intervention. This is confirmed by Vollmer, Prescott, Padawangi, Girot, and Grêt-Regamey (2015) who exemplify how monetary exercises benefit from an additional qualitative analysis to enable proper interpretation of the results.

Third, our method offers insight into the dimensions at which municipalities may improve people's understanding of climate impacts. Especially the understanding of GI's role in climate adaptation can be improved. Flood protection was perceived as an important GI benefit, but temperature regulation was not yet widely recognized. While also Madureira et al. (2015) found that temperature regulation is considered one of the least important urban GI benefits in Portugal and France, many others found cooling services to be perceived as highly important (e.g. Lo and Jim, 2012; Ng et al., 2014; Shackleton et al., 2015). Our study reveals that this contrast may be related to the way the question is framed. Residents currently experienced urban heat as more problematic than flooding, but flooding was expected to become a greater problem in the near future. This indicates that flooding was perceived a greater climate change hazard than heat, while the latter actually causes many casualties and health risks (Norton et al., 2015). Improving people's awareness of heat risks may be necessary, especially among vulnerable groups such as the elderly and poor households (Klein Rosenthal, Kinney, & Metzger, 2014).

Another policy relevant finding is the potential of environmental education to create public support for adaptation measures. We showed that preferences for adaptation measures shift to those that are effective for climate adaptation when residents are informed about a measure's adaptation effect. GI measures such as water plazas and green roofs would be more easily accepted if residents are informed about their adaptation capacity. Other studies found similar effects (Castro et al., 2011) but stress the need for clear policy communication and trust in municipal authorities (Lo & Jim, 2010). Our WTP analysis confirms this latter point. Acceptability can also increase when GI designs are promoted on neighbourhood level to influence neighbourhood norms so that residents do not feel an outsider when they install a rain garden or green roof (Uren, Dzidic, & Bishop, 2015; Visscher et al., 2014).

Fourth and final, this study distinguishes itself by relating survey responses to GIS data of local GI. We found several relations between socio-cultural values and GI fraction. Residents of GI-poor areas showed more concerns about future flood risk while residents of GI-rich areas were more likely to recognize flood protection benefits. Recognition of cooling benefits did not increase with GI fraction, confirming the perceived lesser importance of temperature regulation. Regarding GI design preferences, residents of GI-rich areas preferred water rich parks over wooded parks, whereas residents of GI-poor areas rather preferred new trees being planted than new shrubbery. This last finding is consistent with another Dutch study, performed in Utrecht, which found people living in the greenest streets do not feel the need for new GI measures whereas those living in streets without any GI demand more greenery, especially trees (Klemm, Heusinkveld, Lenzholzer, van Hove, 2015). An urban planning implication that can be distilled from these findings is that tree planting should be prioritised in new residential areas, and that an increase in GI cover may lead to an increase in public awareness of GI's impact mitigation capacity.

The methods used in this study build upon existing methods for measuring socio-cultural preferences. Nevertheless, some limitations need to be accounted for. First, to compare the influence of existing GI on preferences and perceptions we aimed at choosing two neighbourhoods that were comparable except for their GI character. However, often a difference in GI goes together with a difference in socioeconomic profile making it difficult to disentangle the effect of socioeconomic profile and GI availability. Second, although the sample was set-up to account for differences in urban structure and availability of GI, some bias in the sample was unavoidable. To supplement the sample from underrepresented parts of the case study area we went from door to door asking people to participate in the survey and found residents of some streets more willing to participate than others, leading to a slight underrepresentation of non-Dutch respondents. Ethnicity does play a role in GI preferences: a Dutch study found that immigrants prefer functional landscapes while natives prefer wilder nature (Buijs, Elands, & Langers, 2009). Our study found stronger preferences for functional GI in *Tarwewijk*, the neighbourhood with a larger non-Dutch population. Given the consistency in findings we do not expect that a more representative sample would substantially change our findings. Because of the type of data collection few socio-cultural valuation studies use large samples and most are similar or smaller than ours (e.g. Baptiste et al., 2015; Church, 2015; Muratet et al., 2015).

5. Conclusions

The multi-dimensional method adopted in this paper revealed that people's awareness of climate impacts and understanding of GI benefits indeed shape preferences for GI measures. Still, the general picture is that citizens are willing to support climate adaptation through GI as long as the GI is multifunctional, i.e., comes with recreational and aesthetic benefits. We advise cities to create public support not only by making people aware of climate change impacts but also by providing information on the multiple benefits of GI, and to tailor the choice of GI to local preferences. Understanding the different dimensions that shape preferences for GI measures can help urban planners identify more effective policy responses, thus effectively reducing impacts of climate change in cities.

Hazards and human or animal subjects

This work complies with relevant laws and institutional committees.

Acknowledgements

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Appendix A. : Questionnaire

Form 1-Survey

Number		Interviewer		
Date & time	- - 2014 ... : ...	Neighbourhood		Zip code
Weather	dry/rain C°	Location		

This questionnaire is performed by *Vrije Universiteit Amsterdam* for a study about the role and importance of nature in the city, specifically regarding climate change (changing weather conditions). The questionnaire is about green (vegetation) and blue (water) space in your street, neighbourhood, and city. The questions also enquire about your experience with urban heat and flooding.

Part 1: Heat

Heatwaves occur regularly, also in Rotterdam; the last one happened in July 2013. A heatwave brings along tropical temperatures (30°C or higher) from which people may suffer, children and elderly are particularly vulnerable. Last July we also experienced a few very hot days. The following questions enquire about your experience with urban heat.

1. Do you notice that the city is hotter than its direct surroundings, for example the countryside just outside of the city?
   - ☐ Yes
   - ☐ No

2. Do you notice that certain urban areas are hotter than others, for example a difference in temperature between the city centre, residential areas, the park, and a shopping street?
   - ☐ Yes
   - ☐ No → continue with question 5

3. Which locations do you experience as particularly hot? *Fill in the table: **2** hot locations (Form 2)*

4. Which locations do you experience as particularly cool? *Fill in the table: **2** cool locations (Form 2)*

5. During hot days, do you personally experience any problems with high temperatures? *Personal problem*
   - ☐ Yes
   - ☐ No

6. If yes, how do you suffer from heat?

....

7. Climate change is expected to lead to more extreme temperatures that occur more frequently; so no temperature rises to 30 or 31 degrees, but heatwaves of 35 to 37 degrees. Do you perceive this as problematic for the city? *General problem*
   - ☐ Yes
   - ☐ No, I do not worry about this

Part 2: Flooding

When it is raining, a lot of water needs to be discharged. This happens mostly via stormwater drains, and a small share infiltrates the soil. Canals and rivers also serve as storage basins. Still, a heavy rain event may lead to local flooding: streets and basements become flooded and sometimes the water even enters people's homes. This happened just recently, in July. Flooding causes financial damage and may lead to sewage overflow which poses a serious risk to public health.

8. Do you observe any flood prone areas in the city?
   - ☐ Yes
   - ☐ No → continue with question 10

9. Which locations do you experience as particularly flood prone? *Fill in the table: **2** flood prone locations (Form 2)*

10. Do you personally experience any problems with flooding? *Personal problem*
   - ☐ Yes
   - ☐ No

11. If yes, how do you suffer from flooding?

....

12. Climate change is expected to lead to more frequent and extreme rain events. There will be more flooding incidents that last longer, swamping basements and streets so that traffic is hindered and costs rise. Do you perceive this as problematic for the city? *General problem*
   - ☐ Yes
   - ☐ No, I do not worry about this

Part 3: Green and blue space

13. How do you use small green and blue spaces in your neighbourhood? And how do you use large green and blue spaces in the city?

Green and blue space	How often do you visit	How long do you visit	Why do you visit
Park of playground in your neighbourhood  	☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely or never *→continue with Large city park*	☐ Walking/cycling route	☐ Shortest route ☐ Visually attractive
		Visit: ☐ < one hour ☐ one hour ☐ > one hour	☐ Recreation, sports, dog ☐ Visually attractive ☐ Rest, tranquillity ☐ Coolness ☐ ....
Large city park  	☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely or never *→ continue with question 14*	☐ Walking/cycling route	☐ Shortest route ☐ Visually attractive
		Visit: ☐ < one hour ☐ one hour ☐ > one hour	☐ Recreation, sports, dog ☐ Visually attractive ☐ Rest, tranquillity ☐ Coolness ☐ ....

14. Vegetation and water provide several benefits. What benefits do you think that the photographed green and blue spaces provide (Form 3)? *Fill in the table: **2 most important** benefits and **1 least important** benefit per photo*

	Photo 1		Photo 2		Photo 3		Photo 4		Photo 5		Photo 6	
Benefit	Most **2x**	Least **1x**	Most **2x**	Least **1x**	Most **2x**	Least **1x**	Most **2x**	Least **1x**	Most **2x**	Least **1x**	Most **2x**	Least **1x**
Air purification	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Temperature regulation (cooling)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Carbon storage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Traffic noise reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rainwater retention	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Recreation, visually attractive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

15. How important are these benefits to you? *Rank them **from 1 – 6** by placing a number behind each benefit (**1 = most important**)*

Air purification	.....	Carbon storage	.....	Rainwater retention	.....
Temperature regulation (cooling)	.....	Traffic noise reduction	.....	Recreation, visually attractive	.....

16. What types of green and blue space would you like to see (more)? *Fill in the table: **2 favourites** from six types (Form 3)*

	Photo 1	Photo 2	Photo 3	Photo 4	Photo 5	Photo 6
Favourite (2x)	☐	☐	☐	☐	☐	☐

Part 4: Measures for climate adaptation

Rotterdam municipality wants to make the city climate proof by adapting its urban design to changing weather conditions. This means that the city wants to be prepared for more extreme rain and heatwaves in the future.

17. Do you know that Rotterdam municipality wants to make the city climate proof?
☐ Yes
☐ No

18. One way in which the city can be made climate proof is by investing in vegetation and water. The municipality offers measures at different scale levels. For each scale level, we would like to know which measure you prefer. We show you one status quo situation and three measures per scale level and ask you to choose your favorite measure (Form 4). Optional: symbols illustrate the effectiveness of each measure in terms of cooling and rainwater retention. *Fill in the table: **1 preferred measure** per scale level*

	Measure A	Measure B	Measure C
House	☐	☐	☐
Street	☐	☐	☐
Local square	☐	☐	☐
Main road	☐	☐	☐
City park	☐	☐	☐

19. What is your main reason to choose a preferred measure in the previous question?
☐ This is currently lacking in my neighbourhood
☐ This I find most useful and/or visually attractive
☐ The contribution to cooling and rainwater retention
☐ Otherwise, namely: ....

20. To realize green and blue space in Rotterdam, money is needed. How much would you be willing to pay for new green and blue space via municipal taxes? The amount is the additional tax per household per year, so it comes on top of current municipal taxes.
☐ €0 - no investments and no new measures for green and blue space
☐ €5 - only investments for small measures such as vegetated strips at street level
☐ €15 - reasonable investments for measures at street and neighbourhood level
☐ €40 - large investments for measures at all levels: street, neighbourhood, city

In case you are not willing to pay via taxes, but willing to contribute in another way, tick here ☐

21. If answer is €0: What is the main reason that you are not willing to pay?
☐ It is not worth my money
☐ I do not think it is important enough/it has no priority for municipal investments
☐ Otherwise, namely: ....

Part 5: Personal data

22. What is your gender?
☐ Male
☐ Female

23. What is your age?
☐ 16-25
☐ 26-45
☐ 46-65
☐ 66 or older

24. What is your highest completed education level?
☐ No completed education
☐ Elementary school
☐ High school
☐ Middle-level applied education (MBO in Dutch)
☐ Higher professional education (HBO in Dutch)
☐ University (WO in Dutch)

25. What is the composition of your household?
☐ Alone
☐ With partner
☐ With partner and child(ren)
☐ With child(ren)
☐ Otherwise, namely: ....

26. What is your **household** income? Modal: ***gross € 2.585 / nett € 1.866 per month***
☐ Below modal
☐ About modal
☐ About 1.5 times modal
☐ About 2 times modal
☐ More than 2 times modal

27. What is your ethnicity?
☐ Surinamese
☐ Antillean/Aruban
☐ Cape Verdean
☐ Turkish
☐ Moroccan
☐ Other non-western
☐ Dutch
☐ Other Western

28. How long have you been living in Rotterdam?
...... years

Form 2-Locations

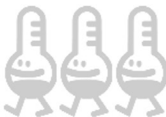
	Hot location *tick **2x***	**Cool location** *tick **2x***
Your home	☐	☐
Your garden	☐	☐
Your street	☐	☐
Shopping street or around shopping centre	☐	☐
Road, square, or parking lot	☐	☐
Playground or open field	☐	☐
Park	☐	☐
Forest	☐	☐
Along the river Meuse or canals	☐	☐
Swimming recreation area	☐	☐
Other, namely:	☐	☐ ....

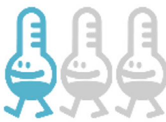
	Flood prone location *tick **2x***
Your home or basement	☐
Your garden	☐
Your street	☐
Shopping street or around shopping centre	☐
Road, square, or parking lot	☐
Playground or open field	☐
Park	☐
Forest	☐
Along the river Meuse or canals	☐
Other, namely:	☐ ....

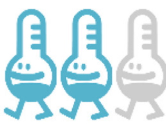
Form 3-Green infrastructure types

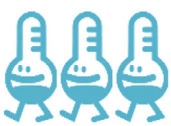
Form 4-Climate adaptation measures

Cooling: temperature regulation


none


low


moderate


high

Flood mitigation: rain water retention

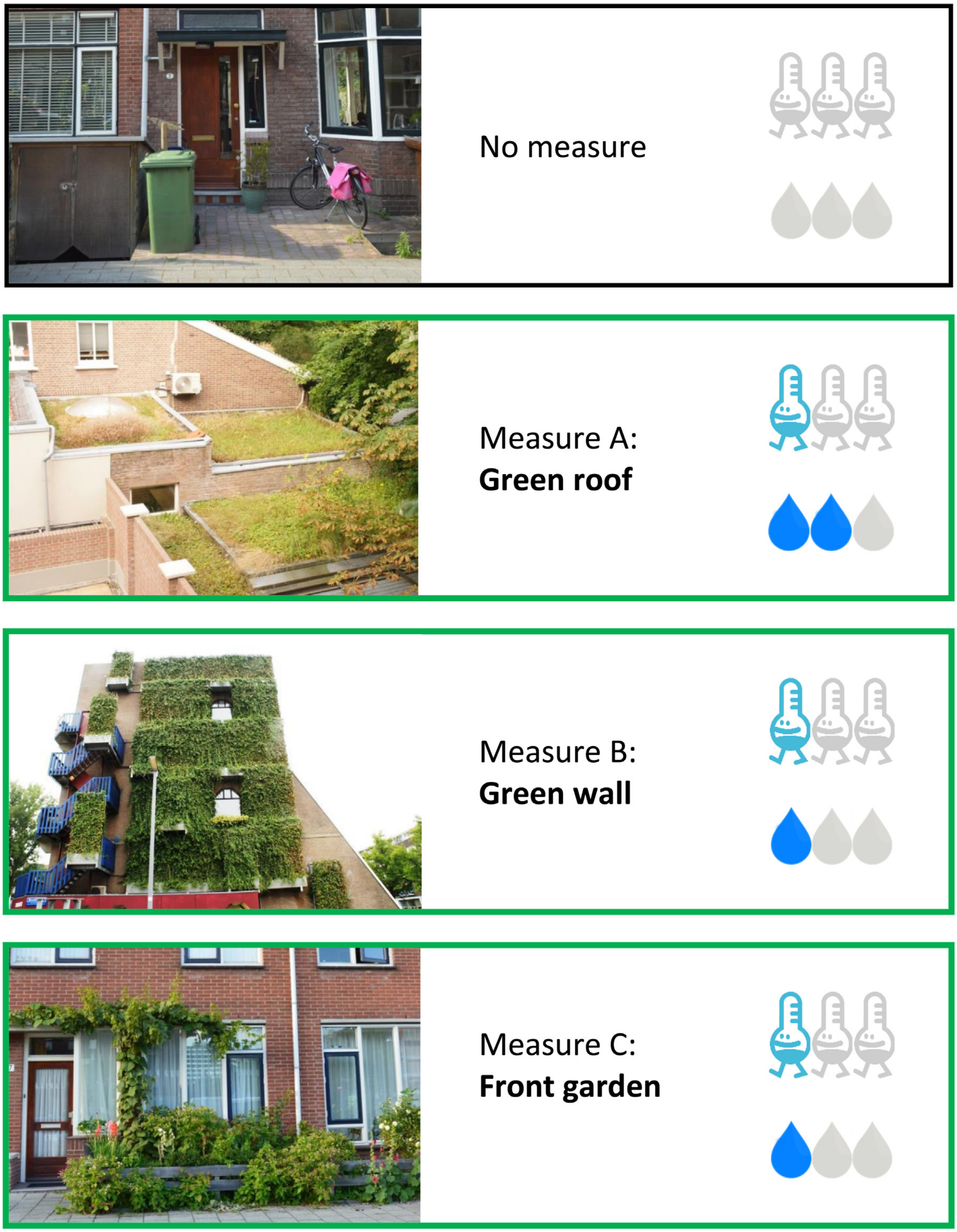
none


low

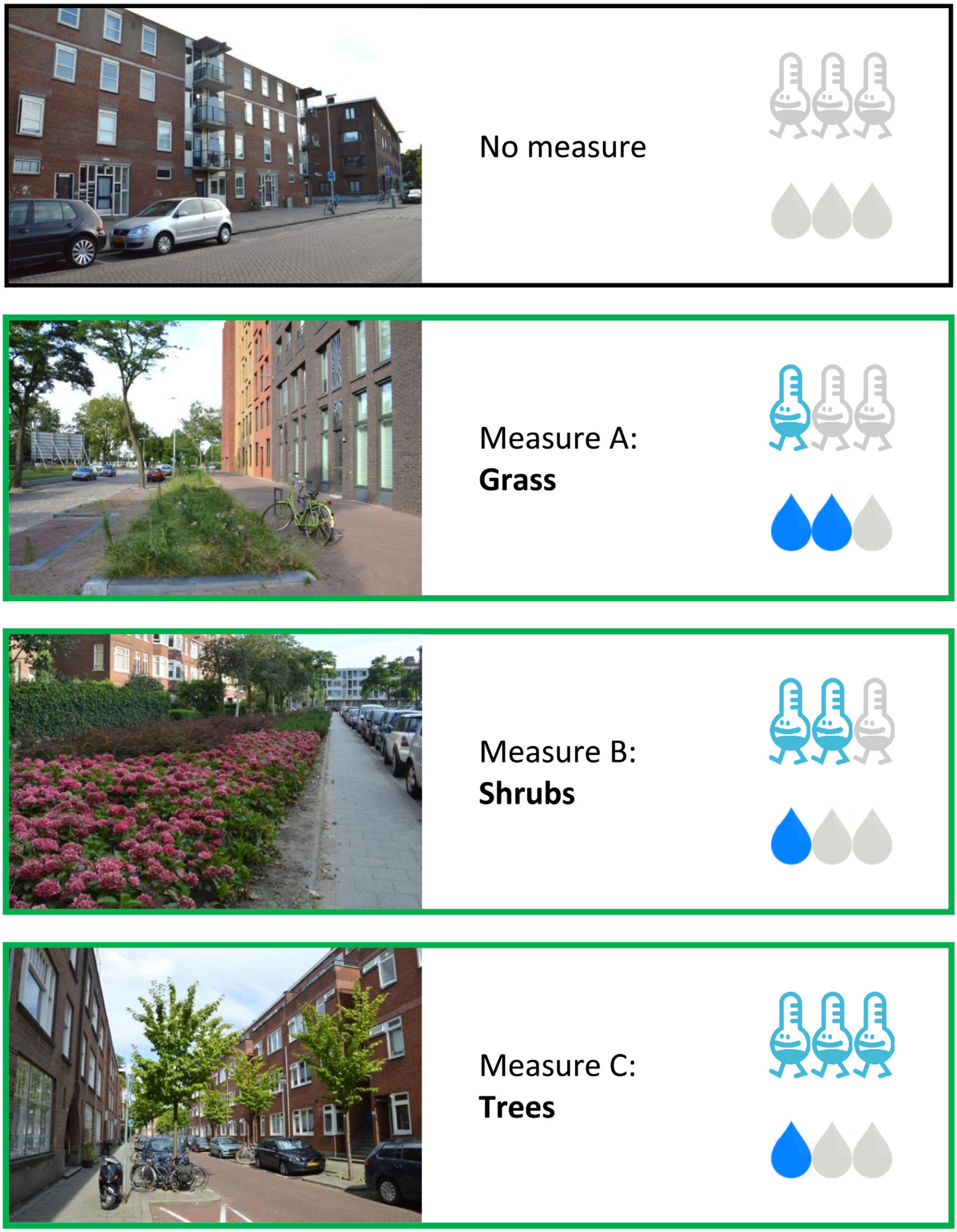

moderate


high

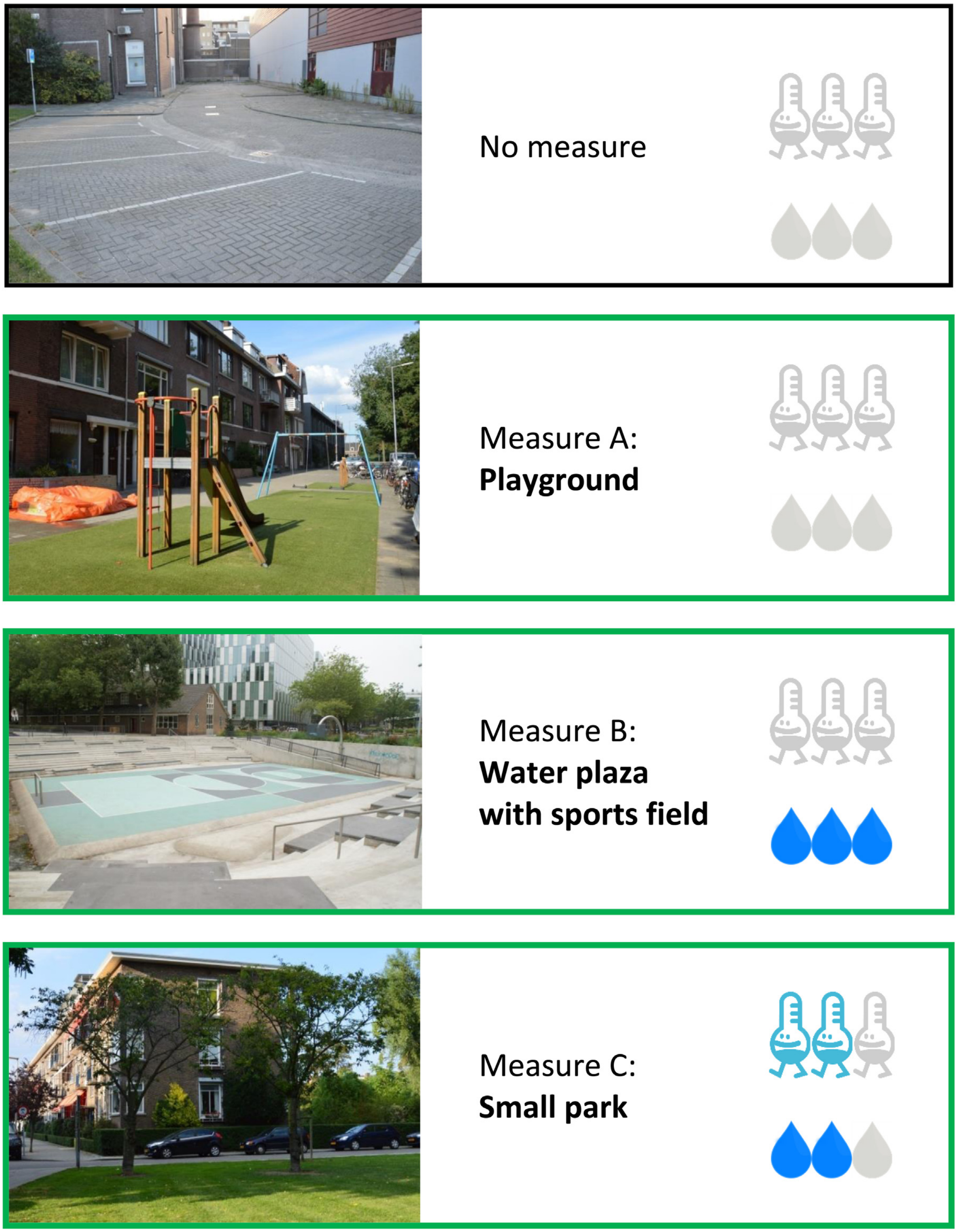
Individual plot: home



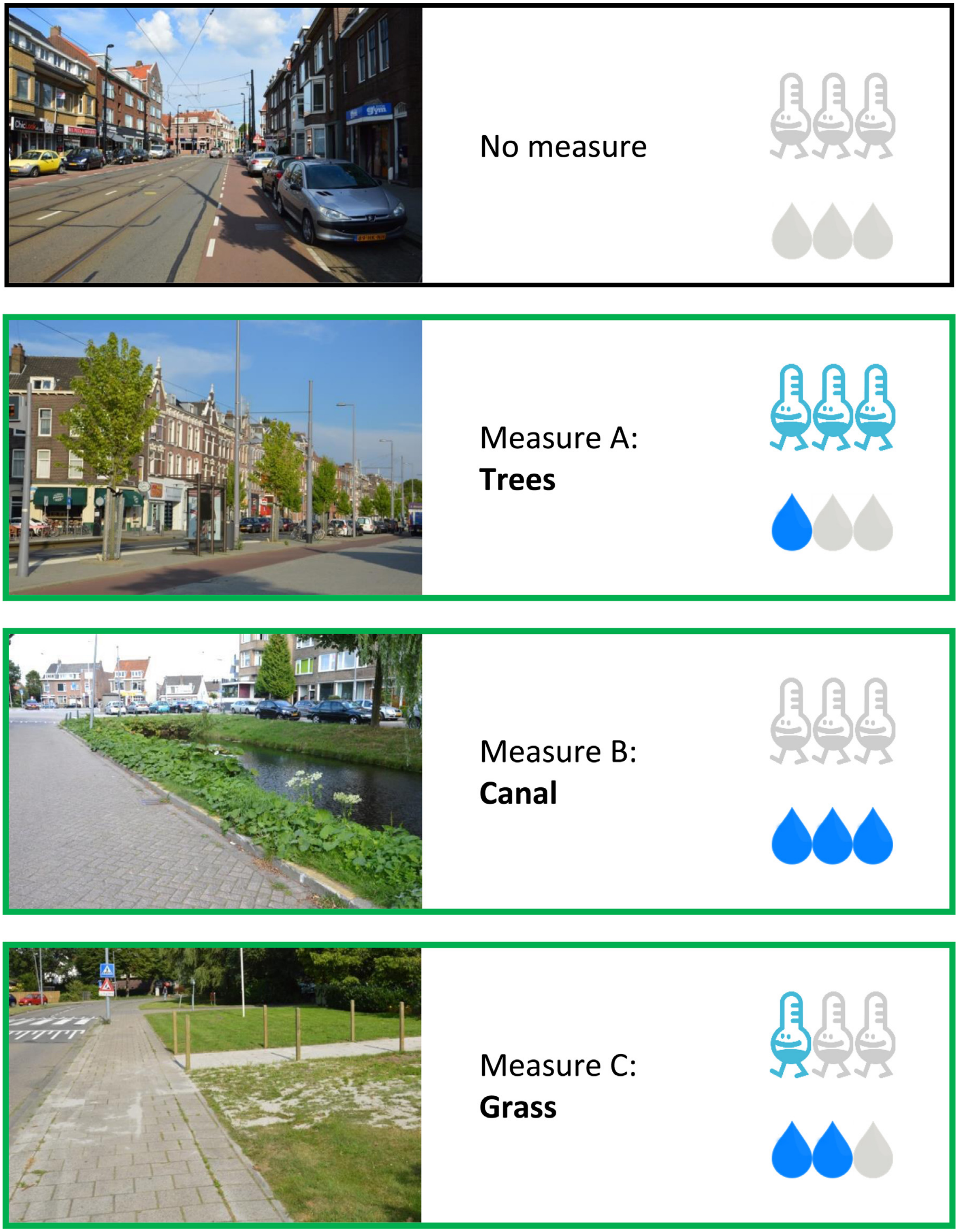
Neighbourhood: street



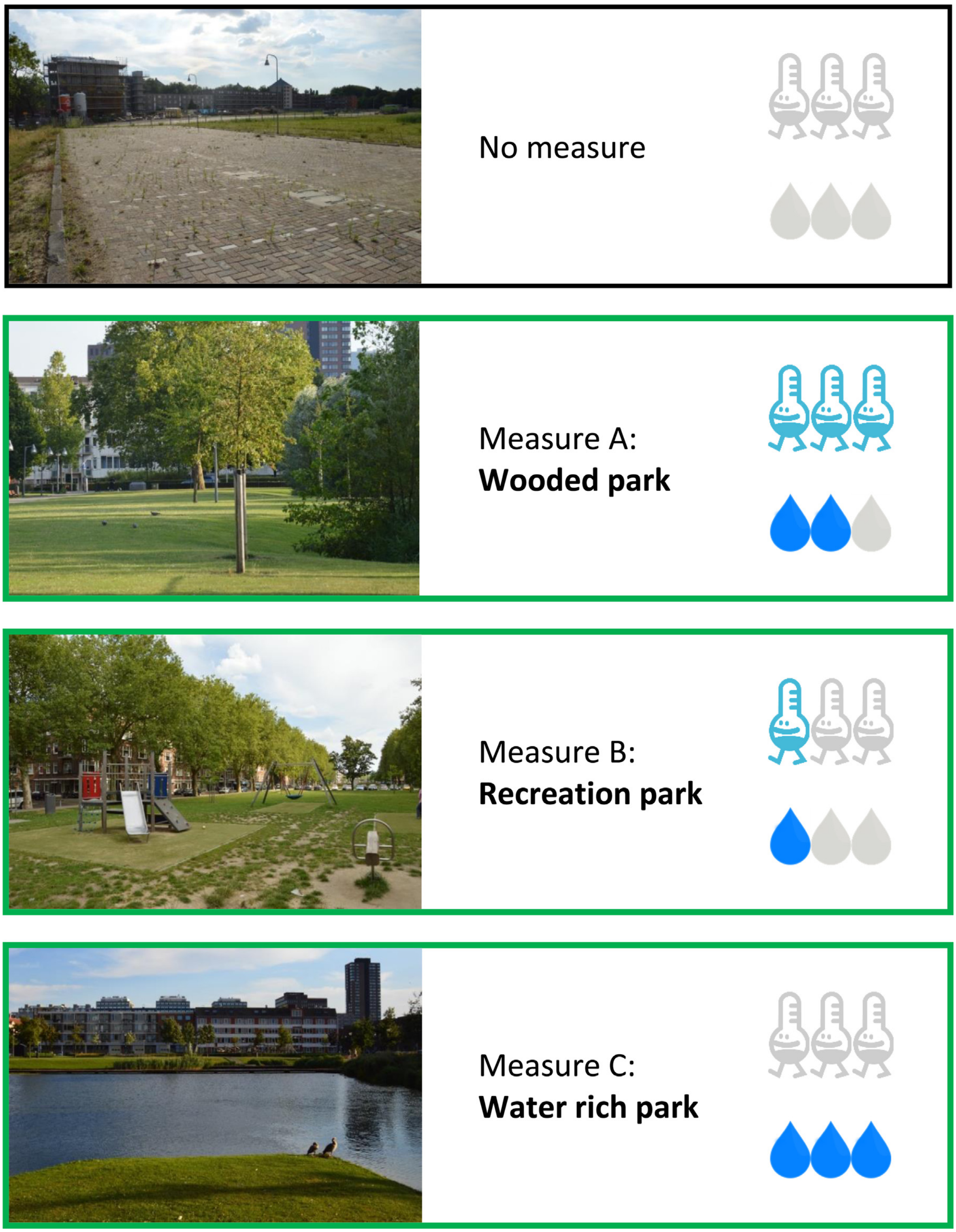
Neighbourhood: local square



City: main road

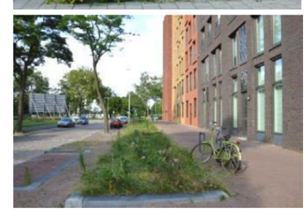


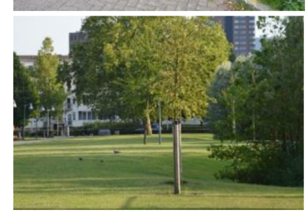
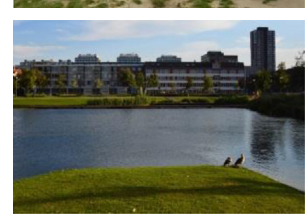
City: city park



Appendix B. Green infrastructure types

Fig. A2 .1. Description of green infrastructure types used in and photographed for the questionnaire

Green infrastructure type	Scale level	Photo used
Green roof Private vegetation on a house roof, consisting of a layered construction on which plants such as mosses, succulents, and herbs grow	Individual plot	
Green wall Private vegetation on a house façade, consisting of panels or frames on which plants grow, either ornamental or edible	Individual plot	
Garden Private garden in front of a house, consisting of a mix of vegetation, water, and sealed surface	Individual plot	
Grass Public strip of herbaceous vegetation (e.g. grass, herbs, small flowers) along the pavement in residential areas	Neighbourhood & City	
Shrubs Public strip of shrubs (e.g. green shrubbery, rosebushes) along the pavement in residential areas	Neighbourhood	
Street trees Public trees along streets in residential areas and along main roads throughout the city, usually standing in a small pit embedded in the pavement	Neighbourhood & City	

Green infrastructure type	Scale level	Photo used
Playground Public outdoor play area purely designed for children's play in residential areas, normally without any vegetation or water	Neighbourhood	
Water plaza Public sports and play field designed for flood control: surface runoff from surrounding streets is directed towards the plaza where it fills up several levels and canals – acting as recreational space and stormwater buffer simultaneously	Neighbourhood	
Small park Public neighbourhood park in residential area, consisting of a lawn, shrubbery, few trees, benches, and sometimes a seesaw or slide	Neighbourhood	
Canal Public waterway along the street, often in a straight shape but not in use for water transport	City	
Wooded park Public city park with a natural character, consisting of trees and their undergrowth and little other infrastructure or facilities	City	
Recreational park Public city park with a recreational character, consisting of lawns and several facilities for sports and play	City	
Water rich park Public city park with a water character, consisting of a lake, pond, or waterway combined with some vegetation (mostly lawns) and wide views	City	

Appendix C. Urban heat and flooding locations

Table A3.1. Locations indicated by respondents as hot, cool, and flood prone

Location	Hot (n = 270) %	Cool (n = 268) %	Flood prone (n = 230) %
Home	20.4	11.9	11.3
Garden	12.6	4.1	8.7
Street	13.3	3.7	23.0
Shopping street, center	27.8	1.9	8.3
Road, square, parking area	14.1	3.0	32.2
Playground, open field	5.9	4.9	8.7
Park	1.9	18.7	3.5
Forest	1.5	23.5	2.6
River, canal	0.4	22.0	1.7
Swimming area	1.9	5.2	0.0
Other	0.4	1.1	0.0
Total	*100.0*	*100.0*	*100.0*

Appendix D. Inter-group differences per scale level

Table A4.1. Differences in preferences for green infrastructure adaptation measures between respondents with or without access to information about adaptation capacity

Scale level	$\chi^2(2)$	*p*-value (n.s. = not significant)
Home	7.019	0.030
Street	4.052	0.044
Local square	13.882	0.001
Main road	0.184	n.s.
City park	9.605	0.008

*Table A4.2. Differences in preference for green infrastructure adaptation measures between respondents from the two neighbourhoods studied (*Tarwewijk *and* Kralingen-West*)*

Scale level	$\chi^2(2)$	*p*-value
Home	10.437	0.005
Street	14.828	0.001
Local square	10.354	0.006
Main road	7.538	0.023
City park	13.953	0.001

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